UNCLASSIFIED

AD_ 295 770

Reproduced
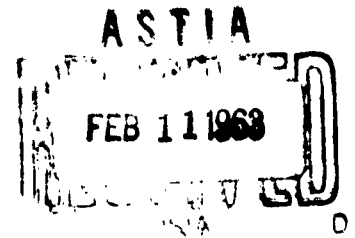*by the*

UNCLASSIFIED

62-1814

METHODS OF CALCULATING NUCLEAR REACTORS
(SELECTED PARTS)

By

G. I. Marchuk

295 770

UNEDITED ROUGH DRAFT TRANSLATION

METHODS OF CALCULATING NUCLEAR REACTORS (SELECTED PARTS)

BY: G. I. Marchuk

English Pages: 42

Date 21 Dec 19 62

B

G. I. Marchuk

METODY RASCHETA YADERNYKH REAKTOROV

Methods of Calculating Nuclear Reactor

by

G. I. Marchuk

Annotation

In the monography are explained basic methods of physical calculation of nuclear reactors. Developed were algorithms for practical utilization of mathematical methods for solvong various problems, originating during the planning of experimental and atomic energy installations. Given are calculated values of critical masses of reactors, which can be used in practical operation.

The book is intended for students-physicists, scientific workers and engineers, specializing in the field of atomic energy.

Foreword

This monography is devoted to methods of calculating nuclear reactors of different spectra . The first effort of giving a systematic explanation of reactor calculation methods was made by the author in his book entitled " Numerical Methods of Calculating Nuclear Reactors " published before the Second International Conference on Peaceful Utilization of Atomic Energy (Geneva, 1958). However since this book appeared on the library shelves many changes have taken place in the methods of calculating reactors. This circumstance prodded the author into writing a monography, in which is described the present day status of problems connected with physical calculation of nuclear reactors. Of course not all mathematical problems of physical calculation are sufficiently well explained in *this* book, but in all instances the author tried to explain all the data with consideration of a certain perspective for further development of methods. Main attention in the monography was devoted to problems of mathematical description of the processes occurring in reactors; problems

concerning the theory of reactors have been touched upon only in minimum extent.

In the book have been reflected problems,developed by the author together with a group of co-workers : Sh.S.Nikolayshvili, Ye.I.Pogudalina, V.V.Smelov, G.A.Ilyasov, F.F.Mikhaylus, V.P.Kochergin, A.I.Vaskin, V.P.Il'in, B.L.Gavrilin, V.V.Varkhomeyeva, Z.N.Milyutina and others.

Calculations of critical masses, mentioned in the book, were carried out under the supervision of author A.I.Nevinnitsa and O.P.Uznadze with active participation of V.P.Kochergin.

Chapter 28 of the book, upon appeal by the author, was written by V.F.Turchin.

Methods of calculating reactors, as explained/ in the book,have been developed and improved under the influence of functions, carried out under the scientific guidance of academician of the Academy of Sciences Ukr-SSR A.I.Leypunskiy.

During all the stages of work the author maintained scientific communication with physicisist-theoreticians: L.N.Usachev, V.V.Orlov, T.N.Zubarev, S.B.Shikhov, V.F. Turchin, V.Ya.Pupko, Ya.V.Shevelev, B.F.Gromov, G.I.Toshinskiy, V.V.Chekunov and others, and also with physicisists-experimentors: I.I.Bondarenko, V.A.Kuznetsov, V.I. Mostov, B.G.Dubovskiy, A.I.Mogil'ner, M.B.Yegiazarov, V.S.Dikarev, E.A.Stumbur and others. The scientific communication with physicists-theoreticians and experimentors has in many instances overcome the trend of work connected with the development of reactor calculation methods.

The author is deeply indebted to A.I.Leypunskiy for numerous evaluations of var_ ious problems concerning the theory of nuclear reactors, which aided in successful development of mathematical methods.

The author is deeply indebted to V.S.Vladimirov for effective evaluation of problems, concerning the transfer of neutrons, as well as to V.F.Turchin, who wrote chapter 28 of the book.

The author is grateful for the evaluation of various mathematical problems con- cerning the theory of neutron transfer, to Ye.S.Kuznetsov, N.N.Yanenko,N.I.Bulyeev.

Great assist in preparing the book for print was given by V.P.Il'in, A.I.Nevinnitsa, and O.P.Uznadze, to whom the author expresses his profound thanks.

G.I.Marchuk

Introduction

Broad application in the calculation of high speed computers created favorable conditions for the development of many fields of science and technology. Newest achievements of computer mathematics enabled to reexamine algorithms for the solution of many problems of mathematical physics and to develop new algorithms, based on the use of numerical methods, submitting to effective realization on computers.

In this way, analytical methods of solving problems have in many instances given place to more effective numerical methods.

The use in calculations of high speed computers enabled to bring forth new problems of science and technology, a greater volume of calculation work of which has previously appeared practically unrealizable. As result such conditions have been created, at which it was found possible to solve more difficult mathematical and logical problems. In this connection, basic importance was acquired by problems, connected with mathematical arrangement of the problems and with the development of effective calculation algorithms.

Successes in the field of computational mathematics have produced a greater effect on the development of the theory and methods of calculating nuclear reactors. After the book by Glesston and M.Edlund [79] , which discussed the elementary bases of the theory of thermal neutron reactors, appeared monographies by A.D.Galanin [59] , devoted to problems of further developing the theory of thermal neutrol base-reactors. General scientific and theoretical bases of atomic energy were explained in books by A.Veynberg and Ye.Vigner [43] , as well as by B.Davison [100]. Finally, in the monography [172] are discussed numerical methods of calculating nuclear reactors.

Up to this day there is no loss in theoretical value of reports of earlier periods

of development of atomic energy. These are reports by Ye.Vigner [44, 47], G.Plachek [227, 228, 231], Peyerls [224], R.Marshak [187, 190], N.N.Bogolyubov [23], I.I.Gurevich and I.Ya.Pomeranchuk [87], G.Vik [48,49], A.Veynberg [44,86], G.Bete [18] and others.

Further development of the theory of nuclear reactors and calculation methods was prompted in the lectures presented at the First and Second International Conferences on Peaceful Utilization of Atomic Energy in Geneva.

Broader development of the theory and methods of calculating nuclear reactors was attained in the USSR in reports by I.V.Kurchatov [157], A.P.Aleksandrov [4], A.I.Alikhanov [5], D.I.Blokhintsev [19,21], V.S.Farsova [296], I.I.Gurevich and I.Ya.Pomeranchuk [87], A.K.Krasin [145,146], S.M.Feynberg [282,286], A.D.Galanin [59,66], V.I.Mostovoy [208], V.V.Orlov [218, 221], B.G.Dubovskiy [97,179], V.F.Turchin [276,277], V.V.Smelov [177,252,253] and others. On the basis of these reports have been scientifically founded projects of nuclear reactors for a greater number of power generating installations , such as the Voronezh, Byeloyarsk atomic electric power stations, the ice breaker LENIN and others, as well as a greater number of experimental reactors with various decelerators and heat carriers [67, 259, 284-286].

The theory and methods of calculating reactors based on intermediate neutrons attained prominence in reports by A.I.Leypunskiy, A.S.Romanovich, L.N.Usachev [278, 280], V.Ya.Pupko [174,235,236], V.A.Kuznetsov, B.F.Gromov, G.I.Toshinskiy, A.I.Mogil'ner , V.V.Chekunov, V.V.Orlov [173,219] and others.

Methods of calculating fast neutron reactors have been developed by A.I.Leypunskiy [163,164], D.I.Blokhintsev [22], L.N.Usachev [278,280], O.D.Kazachkovskiy [124,163,164] I.I.Bondarenko [24,163,164], S.B.Shikhov [216, 310],Yu.A.Stavisskiy [163,164], as well as V.S.Vladimirov [57, 58], Yu.A.Romanov [239] and others. The mentioned reports enabled to scientifically found plans for atomiv power generating stations BR-1 and BR-2 built and put into operation in 1957 and 1959 respectively.

A review of reports of foreign scientists on the theory and methods of calculating

reactors made in reports presente. at the First and Second International Conferences on Peaceful Utilization of Atomic Energy in Geneva [128, 136, 137, 139, 161, 195, 207, 217, 238, 264, 266 and others] .

Substantial development in recent years has been gained also by computational mathematics, the basic results of which were obtained by the group at the V.A.Steklov Math.Inst. at the Academy of Sciences USSR under scientific guidance of academician M.V.Keldysh. The maximum number of results from these investigations pertains to the solution of finite-different equations of elliptical type, as well as to the formula tion of finite-differential eqiations , approximating differential equations with disruptive coefficients.

To solve three-point finite-differential equations of elliptical type I.M.Gel'fand and O.V.Lokutsiyevskiy [166] and , independently, A.S.Kronrod [59] and Stark [314] formulated a factorizing method, which enbaled to reduce a marginal problem to a subsequent solution of three finite-differential (difference) equations of the first order. Next M.V.Keldysh, I.M.Gel'fand and O.V.Lokutsiyevskiy together with K.I.Babenko, V.V. Rusanov and N.N.Chentsov [172] have substantially developed methods for solving finite-difference equations, having developed an apparatus of matrix factorization applicable to systems of difference equations. In particular, this allowed to formulate a new method of solving multidimensional differential equations of elliptical type. The method of matric factorization has produced a decisive influence on the development of numerical methods for solving equations a method of spherical harmonics applicable to problems of atomic energy.

To the study of finite-difference equations, approximating differential equations of elliptical type, have been devoted the investigations by A.N.Tikhonov and A.A. Samarskiy [270-273]. A.N.Tikhonov and A.A.Samarskiy made a thorough investigation of problems concerning the formulation of three-point finite-difference schemes, given are practical algorithms of most rational approximations of differential equations with finite-difference ones, and established were also the general aspects of solutions

of difference equations. They introduced the concept of integral accuracy of a solution of a finite-difference equation relative to the solution of a differential equation and have proven theorems on the convergence of solutions of finite-difference equations. They have proven, in particular, that the formulated by them difference equations in the class of disruptive coefficients have the second integral order of accuracy.

Achievements of computational mathematics have been widely discussed in scientific literature, as well as at conferences and conventions.

All the above mentioned reports on calculationsmethods prepared a base for further development of methods for calculating nuclear reactors. These methods constitute the basic content of this monography.

The book consists of eight parts. The first part   devoted to problems of neutron diffusion. Investigation of the problems is conducted under the assumption, that all neutrons have identical velocity and differ only in direction of the velocity vector.

In chapter 1 is given a brief summary of single speed neutron transfer equations. Derived was an integro-differential equation in various geometries, discussed is the integral equation by Payerls, corresponding to the equation of particle transfer. Special attention was devoted to transport approximation. In conclusion were formula ted problems on critical dimensions of a nuclear reactor.

In chapter 2 are analyzed results of solving transfer equations in case of a point source of neutrons in an infinite medium. The discussion is carried on at first for the case of isotropic diffusion of neutrons.

Next is investigated the problem of asymptotic density of neutrons at greater distances from the source. Using a single speed problem as an example was investigated the method of moments, as well as the method of approximation, developed by Sh.S. Nikolayshvili [215]. In many instances these methods allow to obtain solutions for problems regarding the transfer of neutrons and gamma-quanta.

In chapter 3 are explained numerical methods of solving kinetic equations.

Much attention has been devoted to the best known in physical calculations of nuclear reactors numberical methods by V.S.Vladimirov [57] and B.Karlson [129]. Thoroughly investigated is the problem of improving the convergence of iteration processes, which appear to be the component element of algorithms for ——solving kinetic equations by the Vladimir and Karlson method. Together with the well known method of L.A.Lyusternik, is explained a new method of improving the convergence of the subsequent approximation method, formulated by V.P.Morozov [206]. In conclusion of the chapter is described the variation method for solving neutron transfer equations introduced by V.S.Vladimirov [55].

In chapter 4 are discussed methods of solving integral equations by Payerls. At first is discussed the Krylov-Bogolyubov method, which acquired broad application in solving integral equations. This method is illustrated on a problem concerning the distribution of neutrons within a flat layer. Then special attention is devoted to the method of degenerated nuclei. This method is illustrated by an example of calculating the critical dimension of a homogeneous sphere in case of isotropic, as well as in a simple case - o a nonisotropic indicatrix of neutrol diffusion.

In chapter 5 is given a general description of the spherical harmonics method, developed by G.Vik [48], R.Marshak [167, 189,190], S.Mark [171], B.Davison [100, 102, 103], L.N.Usachev [279], M.Van and Ye.Gut [40], S.Chandrasekar [302] and others, given are also the basic features of the method, supplemented by concrete applications to the case of plane-parallel and spherically-symmetrical systems. Discussed are monodimensional cylindrical systems. Special attention is devoted to P_1-approximation and to diffusion approximation as well.

G.Ya.Rumyantsev has first called attention to the possibility of practically utilizing in calculations of even approximations the method of spherical harmonics, whereby he placed special emphasis on the employment of the P_2-approximation in calculations. It should be pointed out, that G.Ya.Rumyantsev also developed the method of spherical harmonics for arbitrary geometry in problems of setting up

concrete boundary conditions [241, 242] .

A study of the problem concerning the solving of transfer equations in case of a point source in an infinite medium with the aid of the spherical harmonics method was carried out by Sh.S.Nikolayshvili [175,176].

At the conclusion of the chapter is formulated the variational principle introduced by V.S.Vladimirov [50, 51, 55 . On the basis of the variation principle is made a conclusion of equations of spherical harmonics for various geometries in case of isotropic diffusion indicatrices and simultaneously are obtained boundary equations, coinciding with R.Marshak conditions.

It should be pointed out, that the methods,discussed in the first part of the book, are of general nature, and can be applied without any difficulty for solving more difficult problems. Particularly, they can serve as basis for solving problems concerning critical dimensions of a reactor.

Part two of the book is devoted to problems of formulating finite-difference equations of elliptical type, having greater importance in calculating nuclear reactors.

In chapter 6 are discu.sed finite-difference equations of diffusion for mono-dimensional zones. The explanation is done on the basis of above mentioned results obtained by A.N.Tikhonov and A.A.Samarskiy [270-273].

Discussed are simple finite-difference equations of diffusion in the class of discontinuous coefficients. Pointed out are ways of improving finite-difference equations. Formulated were difference equations for systems of two diffusion equations of first order. Introduced into the investigation were finite-difference balance equations, enabling to control the correctness of solving problems in finite-difference formulation. Finally, notes are given on the accuracy of the numerical calculations by finite-difference systems, and a relationship is established between finite-difference equations of continuous calculation and difference equations,formulated with the aid of a method of introducing fictitious points.

In chapter 7 are analyzed the results of formulating finite-difference equations

for two-dimensional zones. Into investigation is introduced a method of formulating difference equations for multidimensional zones in the class of discontinuous coefficients. Described is a matrix form of recording finite-difference equations for two-dimensional zones, and corresponding balance ratios have been formulated.

In chapter 8 is described the formulation of finite-difference equations by the method of spherical harmonics. This formulation is advisable when employing matrix recording of the initial system of ordinary differential equations, constituting together with the boundary conditions a boundary problem. Finite-difference equations formulated for plane-parallel zones with spherical-symmetrical and cylindrical —— geometries. It should be unterlined, that the use of new methods of solving finite-difference equations enabled to considerably raise the effectiveness of applying the spherical harmonics method for solving a wide class of reactor problems.

In chapter 9 are discussed methods of solving finite-difference equations. The most effective method of solving difference equations of elliptical type is the factori— zation method. The method of linear finite-difference factorization allows to effectively solve many problems connected with physical calculation of reactors. Next are descri- bed methods for solving finite-difference diffusion equations for two-dimensional geometry. A corresponding problem could be formulated in vector-matrix form, formally coinciding with a three point linear matrix system. A solution to this problem is found with the aid of the matrix factorization method.

It should, however, be pointed out, that when solving a finite-difference ellip - tical equation by the matrix factorization method at a greater number of unit points it is necessary to deel with matrices of high order. This considerably reduces the possibility of effectively applying matrix factorization for solving the mentioned problems.

N.I.Buleyev made a successful attempt to develop and iteration method, which appears to be a combination of the relaxation process with the method of linear factorization [33, 34].

This method in its simplicity is in no way inferior to the simplest iteration processes of Liebman and Seidel, but converges many times faster.

Among other methods, used successfully for solving two-dimensional finite-difference equations, should be mentioned the method of longitudinal-lateral linear factorization, discussed by J.Douglas [98, 99], I'.N.Yanenko [316, 317] and V.K.Saulyev [246,247].

We must mention, that the effective solution of finite-difference equations of spherical harmonics is realized with the matrix factorization method.

The third part of the book is devoted/ to problems of slowing down (decelerating) neutrons.

Chapter 10 has an introductory nature. In are described the ————————elementary processes, taking place in the nuclear reactor, the structure of the sections where neutrons react with nuclei is estimated and formulated are physical bases for the calculation of a nuclear reactor.

In chapter 11 is given the product of kinetic equation of a reaction. Formulated is an equation for slow down and boundary conditions are fixed. Discussed is a partial case of kinetic equation of a reactor, and namely, problem with constant sections and problem with energy dependence.

In chapter 12 are formulated conjugated equations of a reactor. Given is a general theory of conjugated equations, developed by the author together with V.V.Orlov [173] which generalizes somewhat the known results by Ye.Vigner [43, 44], L.N.Usachev [278, 280], N.A.Dmitriyev [279], N.Fuks [295], B.B.Kadomtsev [120] and B.Davison [100]. Introduced into investigations are important linear functionals and formulated are conjugated equations with respect to the given functionals. Examination of the theory of conjugated equations is completed by a conclusion of formulas of the theory of perturbantion.

Chapter 13 is devoted to diffusion approximation. Following in the steps of R.Marshak [190] the approximated solution of a kinetic equation is sought with the aid of two members of the series in accordance with specific functions. As result we arrive

at two integro-differential equations, forming a closed system of reactor equations. For moderators with $M \gg 1$ the solution of moderation equations is sought in form of a series by lethargy. This allows to free our hands in equations from the integral operator and as consequence the problem is reduced to solving a system of differential equations for functions, depending upon spatial coordinates and lethargy. At the end of the chapter are discussed problems of defining more closely the diffusion-age theory, investigated by Ye.Greyling and D.Gertsel [79].

In chapter 14 are explained methods of solving reactor equations in P_n-approximation allowing to define more closely the solutions obtained in diffusion approximation. Formulated are basic and conjugated equations in P_n-approximations and corresponding boundary conditions. Special attention is devoted to P_3-approximation, presenting greater interest in problems concerning critical mass of reactor.

In fourth part of the book are discussed methods of group representation of reactor equations.

Chapter 15 is devoted to the conclusion of multigroup system of basic and conjugated kinetic reactor equations. The method of group averaging is applied in such a way, that during transition from basic problem to multigroup the most essential functional remained unchanged. If in the role of problem functional is considered the critical dimension of the reactor , then during the formulation of a multigroup system is necessary that the critical mass of the reactor should remain unchanged. If in the role of functional is selected , for example, a dosage of radiation coming out from the reactor, as is the case when calculating the protection against radiation, then during the transition to multigroup problem it is necessary, that the dosage of outcoming radiation should remain unchanged. Naturally, that during the averaging, intended for the preservation of these or any other functionals, there is a change in form of conjugated functions, which are also taken with respect to the fixed functional. If the number of groups increases then the method of averaging appears to be indifferent and, in this way, there is the possibility of compiling universal multigroup constants,

which do not depend upon the neutron spectrum in the reactor. This, in any event, is valid for problems , connected with the calculation of critical mass or reactor reactance. AS to problems pertaining to the passing of neutrons through the protection , then for them, apparently, it is practically impossible to compile a universal multigroup system of constants, valid for calculations of small scale and asymptotic larger protections as well.

In chapter 16 are explained the general algorithms for the obtainment of multigroup reactor equations in P_1-approximation. Explained are methods of averaging physical constants in the ultra-warm zone , given are transforms of formulas for averaged physical constants and simple averaging methods are given.

It should be pointed out, that the problem of most rational averaging of physical constants has gained sufficiently great attention in literature. These problems, in particular, have found reflection (mention) in reports of R.Erlikh and G.Gurvits [314], S.Glesston and M.Edlund [79], L.N.Usachev [279, 280] , G.I.Marchuk [172, 178, 180] and others. In many of the mentioned reports physical constants are averaged for reactors with moderators consisting of a mixture of elements, having no hydrogen.

The method of averaging constants by groups for mixtures, containing hydrogen nuclei, was introduced by G.I.Marchuk and N.Ya.Lyashchenko [286]. Further on this method has been substantially developed by N.Ya.Lyashchenko and applied to a broad class of problems.

In the monography by the author [272] was formulated an approximation calculation method for uranium-water reactors, which can also be applied for physical calculations. In this monography, when discussing problems of multigroup representation of reactor equations the author selected a new way, based on the use of the apparatus of the theory of perturbations, allowing to average the constants with consideration of statistical weights, which appear to be solutions of a multigroup system of conjugated reactor equations with respect to the fixed functional.

In conclusion of chapter 16 are basic and conjugated reactor equations, which are changed into form, convenient for carrying on practical calculations. Great attention is also devoted to the consideration of resonance effects during multigroup calculation.

In chapter 17 are formulated multigroup systems of reactor equations in diffusion-age approximation. Formulas are derived for a multigroup system of constants and ways are discussed for practical realization of the algorithm. Much attention was devoted to the approximated method of calculating spatial-energy distribution of neutrons in the reactor. The obtained neutron spectrum in the reactor can be utilized for multigroup averaging of constants and for more accurate solution of the problem. In conclusion is given a method of calculating the effective addition to the active zone on account of the reflector.

Chapter 18 is devoted to the utilization of the multigroup method to problems in P_n-approximation. Given are effective methods for calculating a multigroup of constants, based on the utilization of the neutron spectrum, obtained in diffusional or P_1-approximations. A special place in the chapter is devoted to P_2-approximation, which in its realization is no more complex, than P_1-approximation.

In the fifth part of the book is developed an effective single-group theory and methods of small group approximation.

In chapter 19 are discussed monogroup kinetic equations, obtained on the basis of rational methods of averaging a multigroup system of kinetic equations. For monogroup averaging) are/ used methods of the theory of perturbations so that single group kinetic equations lead to the very same functional values, as does a multigroup system. Discussed are two averaging methods, based on the use of subsequent approximation methods. On the basis of single group theories is considered the problem of calculating reactor dimensions without reflectors.

In chapter 20 are investigated problems of monogroup theory applicable to diffusional and P_1-approximations. Obtained was a system of basic and conjugated reactor

equations and compiled were formulas for the obtainment of a monogroup system of con-stants. The corresponding formulas are of simple form and are suitable for practical utilization. In paragraph 20.3 are explained effective methods for calculating criti-cal masses. This part of the chapter appears to be the central one , because in it is formulated the method of defining calculations of critical masses of a reactor ,ob-tained in multigroup P_1-approximation. The task of closely defining consists in the fact, that the multigroup calculation in P_1-approximation allows to find single-group constants, which are later used in solving a single group problem in P_n-approximation. Furthermore, the use in calculations of the single-group theory considerable cuts the time of calculating the critical mass of the reactor. The fact is,to calculate the critical mass of a reactor , it is necessary to employ the method of probes, with the aid of which it is possible to find the dimension of the reactor,corresponding to the value $K_{eff} = 1$. To do this it is necessary to make a series of multigroup calcu-lations. If the single group theory is used,then it is sufficient to solve ———the

multigroup\of   system   reactor equations for one value K_{eff} and average the physical constants, so as to obtain coefficients for single group reactor equa-tions. Further calculation is conducted with the aid of the single group theory. As results is found the critical mass of the reactor. Critical mass calculations by the single group theory may have a certain error, because single group constants were obtained by the use of the neutron spectrum in a noncritical reactor $K_{eff} \neq 1$. To define the calculations it is necessary at values, obtained with the aid of single group theory, of critical dimensions and concentration of the spallating isotope, to make a multigroup calculation, and then again average the constants, and with the aid of the single group theory, to define the value of critical parameters of the reactor. Methods based on use of single-group theories for calculating critical masses of reactors, have been developed by the author together with Ye.I.Pogudalina.

In conclusion of the chapter is described a simple, but sufficiently effective approximation method of calculating critical masses of a reactor in single group

approximation , developed by S.B.Shikhov and A.I.Novozhilov [216].

In chapter 21 are developed methods of small-group approximation. It is known, that when calculating nuclear reactors two-or three-group methods are used quite often. In paragraph 21.2 and 21.4 is given the theoretical basis for employing two-group and three-group methods of calculating reactors. Of special importance here is the three-group method, which allows to combine all neutrons of the fission spectrum in one group, neutrons of resonance energies - in another group and thermal energy neutrons - in a third one. This offers the possibility of obtaining not only proper values of critical mass, but also the function of the number of secondary neutrons $Q(r)$. If the three-group system of constants is formulated in diffusional or P_1-approximation, then it can be used further on to define calculations, carried out, for example, within the frame works of P_n-approximations.

In paragraph 21.4 is described an approximate method of two-group calculation of reactors, developed by S.B.Shikhov and V.B.Troyanskiy. This method is highly effective in application to the calculation of reactors of different spectra.

In chapter 22 are discussed problems of the theory of perturbations in case of a single group approximation, as well as in the case of small-group approximations. Obtained were formulae of the theory of perturbations for practically important instances.

In chapter 23 are discussed methods of calculating critical dimensions of reactors in mono-group approximation. Discussed are problems of calculating critical masses of reactors without reflectors. Derived is an approximate formula for calculating critical reactor mass in case of anisotropy in the diffusion of neutrons. Formulated is a variation method for calculating critical masses, given are basic formulae, necessary for calculating critical ———parameters of reactors with homogeneous infinite reflector.

Part six of the book is devoted to the study of heterogeneous —effects in nuclear reactors.

In chapter 24 is explained the theory of resonant entrapment. At first is discussed moderation and entrapment of neutrons in a homogeneous medium. Formulated is a conjugate problem relative to the entrapment of neutrons and under consideration are methods of solving the integral equation of moderating, developed by the author together with F.F.Mikhaylus[181]. Next is discussed the problem of resonant absorption of neutrons in the block. The explanation is made on the basis of the theory of resonant entrapment (resonance capture), developed by V.V.Orlov[218]and, independently, by A.P.Rudik[59]. This theory is valid for the calculation of the effective resonance integral of blocks of any thicknesses and coincides with the theory of N.I. Gurevich and I.Ya.Pomeranchuk[87]for thin blocks and with the Ye.Vigner[79] theory for blocks of greater thicknesses. The dependence of resonance capture upon the temperature of the block has been theoretically investigated by S.Brimberg and Dalstrom [27]. Listed are temperature coefficients for the change in volumetric and surface parts of resonance absorption.Discussed is the problem of mutual screening of lamellar blocks. A corresponding formula to calculate the effective resonance integral was obtained by the author together with V.V.Orlov[172]. At the conclusion of the chapter is considered an important problem of numerically calculating the effective resonance integral in the absorbing block and in the lattice of blocks. This question was brought up by B.Spinrad, Zh.Chernik and N.Korngold[264]. The authors obtained an integral equation of moderation, which is used for finding a central stream of neutrons along the block, necessary to calculate the effective resonance integral. But the theory of B.Spinrod, Zh.Chernik and N.Korngold is applicable only to blocks of greater thicknesses. V.V.Orlov and A.A.Lukyanov[220] developed a theory of resonance capture, based on the use of the integral equation of neutron moderation for blocks of any given thicknesses. Corresponding results are discussed in par.24.8.

In par.24.9 are discussed results *obtained*) by the author and concerning resonance absorption of lamellar systems.

In chapter 25 are weighed problems of effective boundary conditions. Discussed is

the problem of effective conditions on the surface of "black" blocks. A review of the method of effective boundary conditions was made by G.A.Bat and D.F.Zaretskiy [13] . When examining the problem of effective conditions on the boundaries with black bodies is used the balance method developed by A.L.Brudno.

When discussing the boundary conditions for gray bodies was used the method, introduced by D.F.Zaretskiy and D.D.Odintsov [113] and further developed by the author together with T.K .Sedel'nikov [172].

When calculating effective conditions on boundaries with "gray " bodies it is very important to know the probability of neutron capture in the block. To this problem were devoted the investigations by G.Stuart [265, 267] , the results of which are given in the monography. In the chapter under discussion are given applications of effective boundary conditions to the calculation of nuclear reactors. In this respect very essential results have been obtained by A.Amuyal, P.Benua and D.Gorovits [8]. In conclusion is discussed the problem of mutual screening of absorbing blocks in the field of ultra-thermal neutron energies. This problem is of special importance for the obtainment of a proper coefficient of multiplication on fast neutrons of a heterogeneous reactor.

In chapter 26 are formulated effective conditions of homogenizing a heterogeneous reactor. Discussed are two methods of approaching the solution of this problem. The first one of the methods is based on studying the problem on the passing of neutrons in direction, parallel and perpendicular to the generatrix of the block. In diffusion approximation for a plane-parallel medium this problem was investigated by Ya.V. Shevelev [306] . In a more accurate set up it was solved by N.I.Laletin [159] , who also made an effort to develop effective methods of homogenization for cylindrical cells. The second method, developed by V.V.Smelov [252] , is based on the preservation of the reactor's multiplication coefficient during the transition from the heterogeneous system to an equivalently homogeneous. An analogous approach to the solution of the problem of homogenization was developed by A.D.Galanin [66].

In the seventh part of the book are discussed problems of thermalizing neutrons. The first results in thermalization within the frameworks of a model of a monoatomic gas moderator for an infinitely homogeneous medium were obtained by B.N.Davydov in 1937 [93]. These problems were then thoroughly investigated by G.Gurvits [89], Wilkinson [137] Ye.Kogen [137, 138] and others.

In chapter 27 is described a model of a monoatomic gas moderator. Kinetic equa — tions of moderation are discussed. The function of neutron diffusion,constructed by V.V.Smelov and L.V.Mayorov, selected with consideration of the mechanism of elastic diffusion of neutrons on moving nuclei, distributed by velocities in accordance with the Maxwell law. Executed was the transition from kinetic reactor equation to diffusional equations. Formulated was a problem concerning the spectrum of slow neutrons in infini — tely homogeneous medium. In conclusion is presented a problem concerning the spectrum of neutrons in a cell of a heterogeneous reactor and listed are results of calculations, carried out by A.D.Galanin [65].

Chapter 28 was written by V.F.Turchin and represents a review of theoretical re — sults on the scattering of slow neutrons in solid bodies and liquids. Most outstand — ing results in this direction were obtained by V.F.Turchin [276,277], M.V.Kazarnovskiy and F.L.Shapiro [121,123], M.Nelkin [210-212], Ye.Kogen [138, 139] and others.Discussed wa: the diffusion of neutrons by the isolated nucleus and combination of atoms. Great er attention has been devoted to the case of incoherent scattering of neutrons. The central points of this chapter are paragraphs 28.5 and 28.6, in which is discussed the theory of diffusion of slow neutrons in crystals and in liquid. The results,for mulated in these paragraphs, are of greater practical interest and are used in calcu — lations.

In chapter 29 are discussed methods of multigroup solving equations for the spectrum of slow neutrons. An essential feature here is, that the mathematical apparatus,de — veloped for this purpose by the author together with V.V.Smelov [177, 178, 254], is

not connected with the concrete selection of neutron diffusion functions and appears to be universal. On the basis of the theory of perturbations is formulated a single-group theory. Developed was a method for calculating the spectrum of slow neutrons in P_3-approximation of the method of spherical harmonics.

Finally, the eighth part of the book is devoted to critical masses of homogeneous reactors. This part consists of two chapters.

In chapter 30 are considered methods of physically calculating nuclear reactors; formulated are typical problems for the calculation of critical masses and spectra of neutrons; given are practical algorithms for the averaging of group constants; numerous problems were set up which take into consideration the use of small group approximations. In conclusion are discussed problems of calculating heterogeneous reactors and compensation systems. Practically speaking, this chapter has a majority of problems concerning physical calculation and considered are practical algorithms for their solution on the basis of results from previous chapters of the book.

In chapter 31 are presented results of calculating critical masses of reactors in a wide range of neutron spectra: from fast to thermal. The first effort to make a systematic generalization of results obtained from calculation of critical masses of homogeneous reactors was made by V.Ya.Pupko [235, 236] and by T.N.Zubarev, G.I.Marchuk and A.K.Sokolov [115].

In report [115] are listed critical masses of uranium-beryllium, uranium-graphite, and uranium-water reactors, as well as of reactors, consisting of mixtures of U^{235} and Pt^{239}, calculation of which was carried out by the author together with V.P. Kochergin, Ye.I.Pogudalina, V.V.Kolesov, G.A.Ilyasov and L.I.Kuznetsova [183-186]. In recent years these investigations have been repeated by the author together with V.P.Kochergin, A.I.Nevinitsa and O.P.Uznadze on the basis of using a more accurate 21-group system of constants. In addition, a greater number of new variants are con-sidered, essential for the planning of reactors of variegated spectra.

In the appendix to the book are included certain data, useful for practical uti-

lization of methods, analyzed in the monography.

LITERATURE

1. Adamchuk, Yu. V. _Atlas of Effective Neutron Sections of Elements_. Moscow, Publishing House of the Academy of Sciences of the USSR, 1955.

2. Adler, F., Khinma, G., Nordgeym, L. "Methods of Quantitative Evaluations of Resonance Intervals." In the collection: Neutron Physics. Moscow, Atomizdat, 1959, p. 567.

3. Ayns, E. _Ordinary Differential Equations_. ONTI, 1939.

4. Aleksandrov, A. P., Afrikantov, I. I., Brendaus, A. I., Gladkov, G. A., Gnesin, B. Ya., Neganov, V. I., Khlopkin, N. S. "Atomic Ice-breaker, the 'Lenin'." In the collection: Nuclear Reactors and Nuclear Power Engineering. Moscow, Atomizdat, 1959.

5. Alikhanov, A. I., Vladimirskiy, V. V. et al. "Experimental Physical Reactor with Heavy Water." In the collection: Reactor Construction and Theory of Reactors. Moscow, 1955.

6. Amal'di, Ye., Fermi, Ye. (Amaldi, E., Fermi, E.). "On the Absorbtion and the Diffusion of Slow Neutrons." Physics Review, 50, 899 (1936).

7. Ambartsumyan, V. A. "Dispersion and Absorbtion of Light in Planetary Atmospheres". Textbook of the Western Leningrad State University, #82, (1941).

8. Amuyal, A., Benus, P., Gorovits, D. Zh. "New Method of Determining Efficiency of Heat Neutrons in an Elementary Nucleus." Moscow, In the collection: Some Problems of Nuclear Power Engineering. Foreign Literature Publishing House, 1959, p. 237.

9. Aspelund, O. "New Method of Solving Bolzmann Equation in a Transport Approximation." In the collection: Physics of Nuclear Reactors. Moscow, Atomic Publishing House, 1959, p. 433.

10. Akhiyezer, A. I. and Pomeranchuk, I. Ya. _Some Problems of Nuclear Theory_. Moscow, State Technical Publishing House, 1950.

11. Bat', G. A. "Designs of Heterogenous Reactors with a Small Number of Blocks." In the collection: Reactor Construction and Theory of Reactors. Moscow, Publishing House of the Academy of Sciences of the USSR, 1955.

12. Bat', G. A., Zaretskiy, D. F. "Effective Boundary Conditions in the Theory of Diffusion of Neutrons." Atomic Energy. 4, #6, 510(1958).

13. Bat', G. A., Zaretskiy, D. F. "Solution of Miln's Generalized Problems." In the collection: Reactor Construction and Theory of Reactors. 1955.

14. Bekkenbakh, E. _Modern Mathematics for Engineers_. Moscow, Publishing House of the Academy of Sciences of the USSR, 1959.

15. Belkin, V. F., Krupchitskiy, P. A., Sidorov, Yu. S., Shvedov, O. V. "Distribution of Density of Heat Neutrons Along the Radius of Rod-type Heat-distributing Elements." Report #2034. Transactions of the Second International Conference on

the Peaceful Use of Atomic Energy (Geneva, 1958). Reports of Soviet scientists, vol. 2, Moscow, Atomic Publishing House, 1959.

16. Berens, D. (Behrens, D.). "The Effect of Holes in a Reacting Material on the Passage of Neutrons." Proceedings of the Physics Society, 62 (S.A.), 607 (1949).

17. Bete, G. "Theoretical Analysis of Neutron Resonances of Fissionable Materials." In the collection: Progress in the Field of Nuclear Power Engineering. Moscow, Foreign Literature Pub. 1958, p. 119.

18. Bete, G., Tonks, L., Gurvits, G. (Bethe, H., Tonks, L., Hurwitz, H.). "Neutron Penetration and Slowing Down at Intermediate Distances Through Medium and Heavy Nuclei." Physics Review, 80, 1, 11(1950).

19. Blokhintsev, D. I., Nikolayev, N. A. "First Atomic Electrical Power Plant in the USSR and Means of Developing Atomic Power Engineering." In the collection: Reactor Construction and Theory of Reactors. Moscow, Pub. Acad. Sc. USSR, 1955.

20. Blokhintsev, D. I., Dollezhal', N.A., Krasin, A. K. "Reactor of the Atomic Electrical Power Plant of the Acad. Sc. USSR." Atomic Energy. #1, 1956.

21. Blokhintsev, D. I., Minashin, M. Ye., Sergeyev, Yu. A. "Physical and Thermal Calculations of the Reactor of the Atomic Electrical Power Plant of the Acad. Sc. USSR." Atomic Energy. #1, 1956.

22. Blokhintsev, D. I. " Physical and Technical Fundamentals of Atomic Power Engineering." (Report at a session of the Academy of Sciences, Ukrainian SSR). Ukrainian Physics Journal. 1, #3, 209(1956).

23. Bogolyubov, N. N. Problems of Dynamic Theory in Statistical Physics. Moscow, State Tech. and Theoretical Pub. 1946.

24. Bondarenko, I. I., Kuz'minov, B. D., Kutsayeva, L. S., Prokhorova, L. I., Smirenkin, G. N. "Average Number and Spectrum in Fission with Fast Neutrons." Report #2187. Transactions of the Second International Conference on Peaceful Use of Atomic Energy (Geneva, 1958). Rep. of Soviet scientists, vol. 1, Moscow, Atom. Pub., 1959.

25. Boffi, V. "On the Slowing Down of Neutrons in an Homogeneous Infinite Medium." Annual of Physics, 2, 3, 435(1960).

26. Breshenkova, Ye. B., Orlov, V. V. "Solution of a Kinetic Equation in the Case of a Point Mono-directed Source." Atomic Energy, 10, 2(1961).

27. Brimberg, S. and Dal'strom, "Computation of Temperature Coefficient of Effective Resonance Integral for Metallic Uranium and Uranium Oxide." In the collection: Neutron Physics. Moscow, Atom. Pub., 1950, p. 577.

28. O'Brien, G., Hyman, M. and Kaplan, S. "Study of Numerical Solution of Partial Differential Equations." Journal of Math. and Phys., 29, 4(1951).

29. Broder, D. L., Kutuzov, A. A., Levin, V. V., Orlov, V. V. and Turusova, A. V. "Passage of Fast Neutrons Through Lead and Iron." Atom. Ener. 7, #4, 313(1959).

30. Broder, D. L., Kutuzov, A. A., Naumov, V. I., Sergeyev, Yu. A., Kondrashov, A. P. and Turusova, A. V.: "Application of Multi-group Methods for Calculation of Biological Protection." Collection: Theory and Methods of Designing Reactors. State Atom. Pub., 1962. (On the Presses).

31. Broder, D. L., Kurkin, S. A., Kutuzov, A. A., Levin, V. V. and Orlov, V. V. "Study of Spatial-Energy Distributions of Neutrons in Various Media." Report #2147. Transactions of the 2nd Internat. Conf. on Peaceful Use of Atom. Ener. (Geneva, 1958). Rep. of Sov. Scientists, vol. 2, Moscow, Atom. Pub., 1959.

32. Brockhouse, B. "Structural Dynamics of Water by Neutron Spectrometry." Nuovo cimento, Suppl., 9, 1, 45(1959).

33. Buleyev, N. I. "Numerical Method of Solving 2-dimensional and 3-dimensional Diffusion Equations." Mathematics Collection, 51, #2, 227--238 (1960).

34. Buleyev, N. I. "Numerical Method of Solving 2-dimensional Diffusion Equations." Atom. Ener., 6, Issue 3, 338--340(1959).

35. Buckner, H. Uber Konwergenzsatze, Differenzeverfahren auf ein Sturm--Liouvilishes Eigenwertprobleme ergeben. Math. Z., 51, 423(1948).

36. Byakov, V. M. and Ioffe, B. L. "Homogeneous Reactor on Natural Uranium." Rep. #2296. Trans. 2nd Inter. Conf. on Peaceful Use of Atom Ener.(Geneva,1958). Rep. Sov. scientists, vol. 2, Moscow, Atom. Pub., 1959.

37. Vineyard, G. "X-rays and Spectra El. Small--Angle Scattering," Phys. Rev., 94, 751 (1954).

38. Vineyard, G. "Scattering of Slow Neutrons by a Liquid." Phys. Rev., 110, 999 (1958).

39. Vaksprees, E., STOUN, P. and Li, K. "Mathematical Methods of Multi-group Calculations of 2-dimensional Spatial Problems." Rep. #633. Trans. 2nd Inter. Conf. on Peaceful Use of Atom Ener. (Geneva, 1958). Rep. foreign scientists, vol. 3, Moscow, Atom. Pub., 1959, p. 443

40. Wang, M. and Guth, E. "On the Theory of Multiple Scattering Particularily of Charged Particles." Phys. Rev., 84, #6, 1092 (1951).

41. Van Vleck, J. Phys. Rev., 87, 189 (1952).

42. Van Hove, L. "Correlations in Space and Lime and Born Approximation Scattering in Systems of Interacting Particles." Phys. Rev., 95, 249 (1954).

43. Weinberg, A. and Wigner, E. "The Physical Theory of Neutron Chain Reactors," Chicago, 1958.

44. Weinberg, A. "Current Status of Nuclear Reactor Theory." Amer. Jour. Phys., 20, 401 (1952).

45. Weinstock, R. "Inelastic Scattering of Slow Neutrons." Phys. Rev., 65, 1 (1944).

46. Verde, M. and Wick, G. "Some Stationary Distributions of Neutrons in an Infinite Medium." Phys. Rev., 71, 852 (1947).

47. Wigner, E. "Theoretical Physics in the Metallurgiens Laboratory of Chicago." Journ. Appl. Phys., 17, 857 (1946).

48. Wick, G. "On the Space Distribution of Slow Neutrons." Phys. Rev., 75, #5, 738 (1949).

49. Wick, G. Zeitschr. f. Phys., 121 (1943).

50. Vladimirov, V. S. "Mathematical Problems of Single-speed Theory of Transfer of Particles." Trans. Math. Inst. (V. A. Steklov) Acad. Sc. USSR, Moscow, Acad, Sc. USSR Pub., #59 (1961).

51. Vladimirov, V. S. "On Integral-differential Equation of Transfer of Particles." Dissertation. Math. Inst. (V. A. Steklov) Acad. Sc. USSR (1959).

52. Vladimirov, V. S. "Approximate Solution of One Boundary Problem for a Differential Equation of the 2nd Order." Applied Math. and Mech., 19, B-3 (1955).

53. Vladimirov, V. S. "On one Integral-differential Equation." News of Acad. Sc. USSR, Math. Series, #21 (1957), p. 3--52.

54. Vladimirov, V. S. "On an Equation of Transfer of Particles." News of Acad. Sc. USSR, Math. Ser., #22, 475 (1958).

55. Vladimirov, V. S. "On Some Variation Methods of Approximate Solution of a Transfer Equation." In collection: Computer Mathematics. Moscow, Acad. Sc. USSR Pub., #7 (1958).

56. Vladimirov, V. S. "On an Integral Equation Connected with Spherical Functions." Scientific Reports of the Higher School., #6, 142 (1958).

57. Vladimirov, V. S. "Numerical Solution of a Kinetic Equation for a Sphere." In collection: Computer Mathematics, #3, 1958.

58. Vladimirov, V.S. and Sobol', I. M. "Calculation of Least Characteristic Number of Payerl Equation by Monte-Carlo Method." Computer Mathematics, Moscow, Acad. Sc. USSR Pub., 3, 130 (1958).

59. Galanin, A. D. "Theory of Nuclear Reactors Operating on Heat Neutrons." Atom. Pub., 1957.

60. Galanin, A. D. "Computation of the Coefficient of Heat Utilization in a Heterogeneous Reactor." In collection: Reactor Constr. and Theory of Reactors. Moscow, Acad. Sc. USSR Pub., 1955.

61. Galanin, A. D. "On Computation of Coefficient of Heat Utilization." In collection: Neutron Phys. Moscow, State Atom Pub., 1961.

62. Galanin, A. D. "Absorbtion and Multiplicationof Neutrons During Slowing Down in the Theory of Two Groups." Reactor Constr. and Theory of Reactors. Moscow, Acad. Sc. USSR Pub., 1955.

63. Galanin, A. D. "Critical Dimension of a Heterogeneous Reactor with a Small Number of Blocks." In collection: Reactor Constr. and Theory of Reactors. Moscow, Acad. Sc. USSR Pub., 1955.

64. Galanin, A. D. "Utilization of Method of Effective Boundary Conditions for Calculation of Critical Dimensions of a Reactor." In collection: Reactor Constr. and Theory of Reactors. Moscow, Acad. Sc. USSR Pub., 1955.

65. Galanin, A. D. "On Thermalization of Neutrons in a Heterogeneous Reactor." In collection: Neutron Phys. Moscow, State Atom. Pub., 1961.

66. Galanin, A. D. "Theory of Heterogeneous Reactor with Cylindrical Blocks of Finite Radius." Atom. Ener., 9, #2, 89 (1960).

67. Galanin, A. D., Nemirovskaya, S. A., Rudik, A. P., Abov, Yu. G., Belkin, V. F. and Krupchitskiy, P. A. "Critical Experiment on a Heavy-Water Experimental Reactor." Rep. #2036. Trans. 2nd Inter. Conf. on Peaceful Use of Atom. Ener. (Geneva, 1958). Rep. Sov. scientists, vol. 2, Moscow, Atom. Pub., 1959.

68. Gantmakher, F. R. "Theory of Matrices." State Tech. Theor. Pub., 1953.

69. Gelbard, E. "An Iterative Method for Solving the P_1 Equations in Slab Geometry." Nucl. Sci. and Engr., 3, #4 (1958).

70. Gel'bard, E., Davis, J. and Pearson, J.: "Iterative Solutions to the P_1 and the double-P_1 equations." Nuclear Science and Engineering., 5, #36 (1959).

71. Gel'fand, I. N., Feynberg, S. M., Frolov, A. S. and Chentsov, N. N.: "Concerning the Application of a Method of Random Testings (the Monte Carlo method) for Solutions to a Kinetic Equation." Rpt #2141. Trans. of the 2nd Int'l Conf. on Peaceful Use of Atm. Ener. (Geneva, 1958). Rpts of Sov. Scientists. Vol 2, Moscow, Atm. Pub. Hs., 1959.

72. Gel'fond, A. O.: "Calculation of Finite Differences." Moscow. State Tech. & Theo. Pub. Hs. 1952.

73. Germogenova, T. A.: "Concerning Limited Solutions of a Given Number on a Semi-Infinite Interval of an Inhomogeneous Integral Equation with a Nucleus Depending on the Difference of Arguments." Rpts of Aca. of Sc. USSR, 115, #1, 23 (1959).

74. Germogenova, T. A.: "A More Accurate Proximation for Small Angles in Problems Concerning Multiple Fission." Jour. of Ex. and Theo. Phy. Vol 33, #4, (10) p. 1067, Moscow. Aca. of Sc. USSR Pub. Hs., Oct 1957.

75. Germogenova, T. A.: "Extrapolation Length and Density Near the Border in Miln's Spherical Problem." In the Coll. "Some Mathematical Problems of Neutron Physics." MGU Pub. Hs. (1960) P. 80.

76. Gershgorin, S. O.: "Concerning Approximate Integration of a Laplace and Poisson Equation." Pub. Hs. of the Lenin. Tech. Inst., 30 (1927).

77. Hildebrand, F.: "Of the Convergence of Numerical Solutions of the Heat-Flow Equations." Jour. of Math & Phy., 31, #1 (1952).

78. Glauver, R.: "Time Dependent Displacement Correlations and Inelastic Scattering by Crystals." Phy. Rev. 98, 1692 (1955).

79. Glesston, S. and Edlund, M.: "Fundamentals of the Theory of Nuclear Reactors." Moscow. Fgn Lit. Pub. Hs. (1954).

80. Gol'dshteyn, Kh., Tsveyfel, P. and Foster, D.: "The Contemporary State of Experiment and Theory on Slowing Down of Neutrons in a Water-Containing Medium." In the Coll. "Neutron Phy". Moscow. Atm. Pub. Hs. (1959), p. 688.

81. Gordeyev, I. V., Kardashev, D. A. and Malyshev, A. V.: "Handbook on Nuclear Physics Constants for Designing Reactors." Moscow. Atm. Pub. Hs (1960).

82. Gordeyev, I. V., Orlov, V. V. and Sedel'nikov, T. Kh.: "Temperature Dependence of Effective Resonance Integral of Absorbtion." At. Ener. #3, 252 (1957).

83. Gordeyev, I. V., Pupko, V. Ya.: "Evaluation of a Section of Absorbtion of Neutrons with Fragments in the Intermediate Area of Energy and the Action of the Fragments in Intermediate Reactors." Rpt #2223, "Trans. at the Scnd Int'l Conf. on Peaceful Use of Atm. Ener." Geneva (1958). Rpts of Sov. Sc. Vol 1, Moscow. At. Pub. Hs (1959).

84. Gromova, Z. I., Dubovskiy, B. G., Kamayev, A. V. and Orlov, V. V.: "Measurement of Resonance Absorbtion of Neutrons in the Reactor of an Atomic Electrical Power Plant." Atm. Ener. #5, 411 (1957).

85. Gudman, K.: "Scientific and Technical Fundamentals of Nuclear Power Engineering." Vol 1&2, Moscow. Fgn Lit. Pub. Hs. (1950).

86. Guin, R., Tribi, D. and Veymberg, A.: "Experimental and Theoretical Investigations of Critical Assemblies without a Reflector, Containing Acqueous Solutions of Uranium 235." Rpt #593. Trans. of the Scnd Int'l Conf. on Peaceful Use of Atm. Ener. Geneva (1958). Rpts of Fgn Sc., Vol 3, Moscow. Atm. Pub. Hs (1959).

87. Gurevich, I. I. and Pomeranchuk, I. Ya.: "Theory of Resonance Absorbtion in Herogeneous Systems." In the Coll. "Reactor Construction and Theory of Reactors." Moscow. Aca. of Sc. USSR Pub. Hs. (1955).

88. Gurvitts, Kh. and Erlikh, R.: "Systems on Highly Absorbed Nucleus by a Fuel with the Use of Heat and Intermediate Neutrons." In the Coll. "Progress in the Field of Nuclear Power Engineering." Moscow. Fgn Lit. Pub. Hs. (1958). p. 362.

89. Hurwitz, H., Nelkin, M. and Habtler, G.: "Neutron Thermolization." Jour. of Nuc. Sc. and Eng., Vol 1, #280 (1956).

90. Hurwitz, H. and Zweifel, P.: "Slowing Down of Neutrons by Hydrogeneous Moderators." Jour. of App. Phys., Vol 26, #923 (1955).

91. Hurwitz, H. and Erlich, R.: "Comparison of Theory and Experiment for Intermediate Assemblies." Jour. of Reactor Sc. Technique. (1956).

92. Davydov, A. S.: "Theory of Atomic Nucleus." Moscow. Phys. and Math. Pub. Hs. (1958).

93. Davydov, B. I.: From the Jour. of Ex. and Theo. Phys., Vol 7, #1069 (1937).

94. Dardel, G.: "The Interaction of Neutrons with Matter Studied with a Pulsed Neutron Source." Jour. of Trans. of the Royal Inst. of Tech. Vol 75, #1 (1954).

95. Dopshi, G.: "A Method of Simplifying the Geometry of the Active Zone of a Reactor for Physical Calculations." Rpt #325, Trans. of the 2nd Int'l Conf. on Peaceful Use of Atm. Ener. Geneva (1958). Rpts of Fgn Sc., Vol 3, Moscow. Atm. Pub. Hs. (1959).

96. Drozdov, S. I., Zaretskiy, D. F., Kudrin, L. P. and Sedel'nikov, T. Kh.: "On the Formation of a Spectrum of Heat Neutrons." Rpt #2033, Trans. of the 2nd Int'l Conf. on Peaceful Use of Atm. Ener. Geneva (1958). Rpts of Sov. Sc. Vol 1, Moscow. Atm. Pub. Hs. (1959).

97. Dubovskiy, B. G.: "Sectioning Reactor Systems." Atm. Ener. Vol 7, #5, 456 (1959).

98. Douglas, J.: "On the Relation Between Stability and Convergence in the Numerical Solution of Linear Parabolic and Hyperbolic Differential Equations." Jour. of the Soc. of Indus. App. Math., Vol 4 (1956).

99. Douglas, J.: "On the Numerical Integration of by Implicit Methods." Jour. of the Soc. of Indus. and App. Math., Vol 3, #42, (1955).

100. Davison, B.: "Theory of Transfer of Neutrons." Moscow. Atm. Pub. Hs. (1960).

101. Davison, B.: "Remarks on the Variational Methods." Phys. Rev. Vol 71, #694 (1947).

102. Davison, B.: "Mathematicians in Nuclear Theory." Canad. Math. Bull., Vol 2, 59 (1959).

103. Davison, B.: "Influence of a Black Sphere and Black Cylinder Upon the Neutron Density in an Infinite Non-Capturing Medium." Proceedings of the Phys. Soc., A64, 881 (1951).

104. Davison, B. and Mandl, M.: "On the Neutron Spectrum for V^{-a} Absorption Cross Section." Proc. of Phys. Soc. A67, 967 (1954).

105. Dyad'kin, I. G.: "Space Energy Angular Distribution of Neutrons in Multi-Component, Including Hydrogen, Unlimited Media." In the Coll. "Neutron Phys". Moscow. State Atm. Pub. Hs. (1961).

106. Yegiazarov, M. B., Dikarev, V. S., Madeyev, V. G.: "Measurement of Resonance Absorption of Neutrons in Uranium—Graphite Lattice." Session of the Aca. of Sc. USSR on Peaceful Use of Atm. Ener.,(1-5 June 1955). Meeting of the Dep't of Phys. and Math. Sc.

107. Yemel'yanov, V. S.: "The Future of Atomic Power Engineering in the USSR." Rpt #2027, Trans. of the 2nd Int'l Conf. on Peaceful Use of Atm. Ener. Geneva (1958). Rpts of Sov. Sc., Vol 2, Moscow. Atm. Pub. Hs. (1959).

108. Berezin, I. S. and Zhidkov, N. P.: "Methods of Calculus." Chap. 1 & 2. Moscow. Phys. & Math. Pub. Hs. (1960).

109. Zhukov, A. I.: "Limited Theorum for Different Operators." Prog. of Math. Sc., Vol 14, #129 (1959).

110. Zhukov, A. I.: "Concerning the Convergence of a Solution to a Differential Equation Towards The Solution of A Different Equation." Rpts of the Aca. of Sc. USSR, 117, #2, 174 (1957).

111. Zhukov, A. I., Lokutsiyevskiy, O. V., Samarskiy, A. A. and Ryaben'kiy, V. S.: "Report at the Mathematical Congress, 1956."

112. Zagrafov, V. G.: "Method of Estimating Critical Parameters of Bodies of a Derived Shape Made from Fissionable Substance." Atm Ener. 8, #1, 23 (1960).

113. Zaretskiy, D. F. and Odintsov, D. D.: "Effective Boundary Conditions for 'Gray Bodies'." In the Coll. "Reactor Construction and Theory of Reactors." Moscow. Aca. of Sc. USSR Pub. Hs. (1955).

114. Zemach, A. and Glauber, R.: "Dynamics of Neutron Scattering by Molecules." Phs. Rev. 101, 118, (1956).

115. Zubarev, T. N., Marchuk, G. I. and Sokolov, A. K.: "Critical Masses of Homogeneous Reactors and Nuclear Safety." Account of the Aca. of Sc. USSR (1960).

116. Zubarev, T. N.: "On the Stability of Heat Distribution in a Pulsed Reactor." Atm. Ener. 7, #5, 421 (1959).

117. Zubarev, T. N.: "Pulsed Reactor." Atm. Ener. 5, #6, 605 (1958).

118. Zubarev, T. N.: "Introduction to the Theory of Nuclear Reactors." MAI Pub. Hs. (1959).

119. Eddy, R.: "Stability in a Numerical Solution of Initial Value Problems in Partial Differential Equations." Naval Ord. Lab. Memo. 10 (1949).

120. Kadomtsev, B. D.: "On the Function of Influence in the Theory of Transfer of Radiant Energy." Rpts of the Aca. of Sc. USSR 113, #3, (1957).

121. Kazarnovskiy, M. V.: "Space-Energetic Distribution of Neutrons in a Heavy Gaseous Inhibitor." Exp. and Theo. Phys. 33, #6, 12, 1533 (1957).

122. Kazarnovskiy, M. V. and Shapiro, F. L.: "Theory of Diffusion of Heat Neutrons with the Allowance for Distribution of Velocity." In the Coll. "Neutron Phy." Moscow. State Atm. Pub. Hs. (1961).

123. Kazarnovskiy, M. V., Stepanov, A. V. and Shapiro, F. L.: "Thermolization and Diffusion of Neutrons in Heavy Media." Rpt #2148, Trans. of the 2nd Int'l Conf. on Peaceful Use of Atm. Ener. Geneva (1958). Rpts of Sov. Sc., Vol 2, Moscow. Atm. Pub. Hs (1959).

124. Kazachkovskiy, O. D.: "Economics of Nuclear Fuel in Fast Power Reactors." Rpt 2028, Trans. of the 2nd Int'l Conf. on Peaceful Use of Atm. Ener. Geneva (1958). Rpts of Sov. Sc., Vol 2, Moscow. Atm. Pub. Hs. (1959).

125. Kalligan, D.: "Homogeneous Critical Systems." In the Coll. "prog. in the Fld. of Nuclear Power Eng." Moscow. Fgn Lit. Pub. Hs. (1958).

126. Kamayev, A. V., Dubovskiy, B. G., Vavilov, V. V., Popov, G. A., Palamarchuk, Yu. D. and Ivanov, S. P.: "Experimental Study of the Effects of the Interaction of Two Subcritical Reactors." In the Coll. Crit. Masses of Reactors. Moscow. State Atm. Pub. (1961).

127. Kantorovich, L. V. and Krylov, V. I.: "Approximate Methods of Higher Analysis." GITTL (1950).

128. Kaplan, I. and Chernik, D.: "Uranium—Graphite Lattices. Brucheiven's Reactor." In the Coll. Exp. Reactors and Phys. of Reactors. Moscow. State Tech. and Theo. Pub. Hs. (1956).

129. Karlson, B. and Bell , J.: "Solution to a Transport Equation by the Sn-Method." In the Coll., Phys. of Nuc. Reactors. Moscow. Atm. Pub. Hs.(1959), p. 408.

130. Cassels, J.: "The Inelastic Scattering of Very Slow Neutrons by Aluminum." Proc. of the Royal Soc., A208, 527 (1951).

131. Kakhan, T. and Gozi, M.: "Physics and Design of Nuclear Reactors." Moscow. Atm. Pub. Hs. (1960).

132. Kellog, O.: "On the Existance of Closure of Sets of Characteristic Functions." Math. Annual, 86, 14,1922 .

133. Case, K.: "Elementary Solutions of the Transport Equations and their Applications." Ann. Phys. 9,1 (1960).

134. Case, K., Koffmann, F. and Placzek, G.: "Introduction to the Theory of Neutron Diffussion." Los Alamos (1953).

135. Klimov, V. N.: "Kinetic Equation for Impurities." In the Coll., Theory of Probabilities and Its Applications. 2, #2, 266 (1957).

136. Kodd, D., Sheferd, L. and Tayt, D.: "Physics of Reactors Operating on Fast Neutrons." In the Coll., Prog. in the Fld of Nuc. Power Eng. Moscow. Fgn Lit. Pub. Hs. (1958), p. 289.

137. Kogen, Ye.: "Survey of Theories of Slowing Down of Neutrons to Heat Energies." In the Coll., Exp. Reac. and Phys. of Reac. Moscow. St. Tech. and Theo. Pub. Hs. (1956).

138. Cohen, E.: "The Neutron Velocity Spectrum in a Heavy Moderator." Jour. of Nuc. Sc. and Eng. 2, 227, (1957).

139. Cohen, E.: "Recent Works on Thermolization of Neutrons." In the Coll. Neutron Phys. Moscow. Atm. Pub. Hs. (1959), p. 634.

140. Kozlov, N. I.: "Application of a Variation Method for Determining the Parameters of a Critical Spherical Reactor." In the Coll., Some Math. Prob. of Neutron Phys. MGU Pub. Hs. (1960), p. 143.

141. Kollatts, L.: "Numerical Methods for Solving Differential Equations." Moscow. Fgn Lit. Pub. Hs. (1953).

142. Kondrat'yev, K. Ya.: "Radiant Energy of the Sun." Moscow. Gidrometizdat. (1954).

143. Kothari, L. and Singwi, K.: "Cold Neutron Scattering in Aluminum." Philos. Magazine 2, 694 (1957).

144. Kochergin, V. P. and Orlov, V. V.: "The Length of Slowing Down of Neutrons." Atm. Ener. 6, #1, 34 (1959).

145. Krasin, A. K., Dubovskiy, B. G.: "Physical Beryllium Reactor." Atm. Ener., #4 (1956).

146. Krasin, A. K., Dubovskiy, B. G., Lantsov, M. N., Glazkov, Yu. Yu., Goncharov, R. K., Kamayev, A. V., Geraseva, L. A., Vavilov, V. V., Inyutin, Ye. I., and Sechenkov, A. P.: "Study of the Physical Characteristics of a Reactor with a Beryllium Inhibitor." In the Coll., Nuc. Reac. and Nuc. Power Eng. Moscow. Atm. Pub. Hs. (1959).

147. Kreyts: "Measurement of Resonance Integrals in Uranium." (1944) Materials of the Com. on Atm. Ener. of the USA. Nuc. Reac. Moscow. Fgn. Lit. Pub. Hs. (1956), p. 217.

148. Cribier, D. and Gakrot, B.: "Quasi-Elastic Diffussion of Cold Neutrons by the Coefficient of Liquid Autodiffusion." Jour. of Phys & Radium., 21, 69 (1960).

149. Kuznetsov, Ye. S.: "The Theory of Non-Horizontal Visibility." News of Aca. of Sc. USSR. Geophy. Ser. #5 (1943).

150. Kuznetsov, Ye. S.: "Radiant Equilibrium of a Gas Envelope Surrounding an Absolutely Black Sphere." News of Aca. of Sc. USSR. Geophys. Ser. #3 (1951).

151. Kuznetsov, Ye. S.: "General Method of Constructing Approximate Transfer Equations of Radiant Energy." News of Aca. of Sc. USSR. Geophys. Ser. #4 (1954).

152. Kuznetsov, Ye. S. and Ovchinskiy, B. V.: "Results of a Numerical Solution to an Integral Equation of the Theory of Light Dispersion in the Atmosphere." Trans. of the Geophys. Inst. of the Aca. of Sc. USSR #4 (1949).

153. Kurant, R. and Gilbert, D.: "Methods of Mathematical Physics." Vol 1, St. Tech. Pub. Hs. (1951).

154. Kurant, R., Fridikhs, K. and Levi, G.: "Concerning Different Equations of Mathematical Physics." Prog. of Math. Sc., #8 (1940).

155. Kourganoff, B. and Busbridge, J: "Basic Methods in Transfer Problems." Oxford (1952).

156. Kukhtevich, V. I., Kazanskiy, Yu. A., Nikolayshvili, Sh. S. and Tsypin, S. G.: "Passage of Dispursed Gamma Radiation in Water." Atm. Ener. 4, #2 (1958), p. 138.

157. Kurchatov, I. V.: "Some Problems in the Development of Atomic Energy in the USSR." (Lecture read on the 25th April 1956 in the English Scientific Research Center in Harwell). Atm. Ener. #3, 5 (1956).

158. Ladyzhenskaya, O. A.: "Complex Problem for Hyperbolic Equations." Moscow. St. Tech. and Theo. Pub. Hs. (1953).

159. Laletin, N. I.: "Distribution of Neutrons in a Heterogeneous Medium." In the Coll., Nuc. Reac. and Nec. Pow. Eng. Moscow. Atm. Pub. Hs. (1959).

160. Landau, L. D., Meyman, N. N. and Khalatnikov, I. N.: "Numerical Methods of Integrating Equations in Partial Derivitives by a Method of Grids." Trans. of the 3rd all-union Math. Cong. Moscow. Aca. Sc. USSR Pub. Hs., Vol 2 (1956).

161. Lovenshteyn, V. and Okrent, D.: "Fundamental Positions of Physics of Power Reactors Operating on Fast Neutrons." Rpt #637, Trans. of the 2nd Int'l Conf. on Peaceful Use of Atm. Ener. Geneva (1958). Rpts of Fgn Sc., Vol 3, Moscow. Atm. Pub. Hs. (1959).

162. Lewy, H.: "On the Convergance of Solutions of Difference Equations." N. Y. (1948).

163. Leypunskiy, A. I., Abramov, A. I., Et. Al.: "Investigations on the Physics of Reactor Operating on Fast Neutrons." Rpt #2038, Trans. of the 2nd Int'l Conf. on Peaceful Use of Atm. Ener. Geneva (1958). Rpts of Sov. Sc., Vol 2, Moscow. Atm. Pub. Hs. (1959).

164. Leypunskiy, A. I., Grabin, B. G., Et. Al.: "Experimental Fast Reactors in the USSR." In the Coll., Nuc. Reac. and Nuc. Pow. Eng. Moscow. Atm. Pub. Hs. (1959).

165. Liebmann, H.: "Approximate Determination of Harmonic Functions and Conformal Mapping." Trans. of the Aca. of Math. and Phys. Sc. (1918).

166. Lokutsiyevskiy, O. V.: "Numerical Methods of Solving Equations in Partial Derivitives." All-Union Conf. on Functional Analysis and Its Applications. Prog. of Math. Sc. 9, #3, (69), 224 (1956).

167. Luk'yanov, A. A. and Orlov, V. V.: "Theory of Effective Sections in the ARea of Partial Overlapping of Resonances for Heavy Nuclei." Atm. Ener., #3 (1961).

168. Luk'yanov, A. A. and Orlov, V. V.: "The Influence of a Resonance Structure of Sections on Diffusion of Neutrons." In the Coll., Neut. Phys. Moscow. State Atm. Pub. Hs. (1961).

169. Maklin, R. and Pomerans, G.: "Resonance Capture Integrals." In the Coll., Prog. in the Field of Nuc. Ener. Moscow. For. Lit. Pub. (1958), p. 203.

170. Mandl, M. and Howlett, J.: "A Method for Calculating the Critical Mass of an Intermediate Reactor." Rep. #430 at the Intn'l. Conf. on Peaceful Use of Atm. Ener. (Geneva, 1955).

171. Mark, C.: "Neutron Density Near a Plane Surface." Phys. Rev., 72, 558 (1947).

172. Marchuk, G. I.: "Numerical Methods of Calculating Nuclear Reactors." Moscow, Atm. Pub., 1958.

173. Marchuk, G. I. and Orlov, V. V.: "On a Theory of Conjugate Functions." In the Coll., Neutron Phys., Moscow, State Atm. Pub., 1961.

174. Marchuk, G. I., Pupko, V. Ya., Pogudalina, Ye. I. et al.: "Some Problems of Physics of Nuclear Reactors and Methods of Their Calculation." Rep. #2151. Trans. of the 2nd Intern'l. Conf. on Peaceful Use of Atm. Ener. (Geneva, 1958). Rep. of Sov. Scientists, vol. 2, Moscow, Atm. Pub., 1959.

175. Marchuk, G. I. and Nikolayshvili, Sh. S.: "Application of a Method of Spherical Harmonics to a Transfer Theory." I. Some Properties of P_n-approximation. Coll., Theory and Methods of Calculating Reactors. State Atm. Pub., 1962. (on the presses).

176. Marchuk, G. I., Nikolayshivili, Sh. S., Pogudalina, Ye. I. et al.: "Application of a Method of Spherical Harmonics to Problems of the Theory of Transfer." II. P_2-approximation. Coll., Theory and Methods of Calculating Reactors. State Atm. Pub., 1962. (on the presses).

177. Marchuk, G. I. and Smelov, V. V.: "On the Theory of the Coefficient of Thermal Utilization with Allowance for Thermalization of Neutrons." In the Coll., Neutron Phys., Moscow, State Atm. Pub., 1961.

178. Marchuk, G. I. and Smelov, V. V.: "Multigroup Method of Calculating Space-Energy Distribution of the Flow of Heat Neutrons and Application of the Theory of Disturbances." In the Coll., Neutron Phys. Moscow, State Atm. Pub., 1961.

179. Marchuk, G. I., Dubovskiy, B. G., Smelov, V. V. and Milyutina, Z. N.: "On the Calculation of Sectioned Nuclear-Power Plants." In the Coll., Critical Masses of Reactors. Moscow, State Atm. Pub., 1961.

180. Marchuk, G. I.: "On a Problem Concerning a Multigroup Method of Calculating Nuclear Reactors." Supplement #1 to Atm. Ener., 1958.

181. Marchuk, G. I. and Mikhaylus, F. F.: "Slowing Down of Neutrons in a Medium with Resonance Absorbtion." Atm. Ener., #6 (1958).

182. Marchuk, G. I.: "Multigroup Method of Calculating a Reactors of an Atomic Electrical Power Plant." Atm. Ener., #2 (1956).

183. Marchuk, G. I., Ilyasova, G. A., Kolesov, V. Ye. et. al.: "Critical Masses of Uranium-Beryllium Reactors." In the Coll., Invest. of Crit. Parameters of Reactor Systems. Moscow, State Atm. Pub., 1961.

184. Marchuk, G. I., Ilyasova, G. A., Kolesov, V. Ye. et al.: "Critical Masses of Aqueous Mixtures of Compounds of Uranium and Plutonium." In the Coll., Invest. of Crit. Param. of Reac. Sys. Moscow, State Atm. Pub., 1961.

185. Marchuk, G. I., Ilyasova, G. A., Kolesov, V. Ye. et al.: "Critical Masses of Uranium-Graphite Reactors." In the Coll., Invest. Crit. Param. Reac. Sys., Moscow, State Atm. Pub., 1961.

186. Marchuk, G. I. and Kochergin, V. P.: "Approximate Method of Calculating Critical Masses of Spherical Reactors with an Infinite Reflector." In the Coll., Invest. Crit. Param. Reac. Sys. Moscow, State Atm. Pub., 1961.

187. Marshak, R.: "Note on the Spherical Harmonic Method as Applied to the Milne Problem." Phys. Rev., 71, 443 (1947).

188. Marshak, R.: "Variational Method for Asymptotic Neutron Densities." Phys. Rev., 71. 668 (1947).

189. Marshak, R.: "Theory of the Slowing Down of Neutrons by Elastic Collision with Atomic Nuclei." Phys. Rev., 19, 185 (1947).

190. Marshak, R., Brooks, H. and Hurwitz, H.: "Introduction to the Theory of Diffusion and Slowing Down of Neutrons." Nucleonics, 4, 6, 43 (1949); 5, #1, 69 (1949).

191. Maslennikov, M. V.: "Milne Problem with a Derived Indicatrix." Rep. Acad. Sc. USSR, 118, #5, 895 (1958).

192. Maslennikov, M. V.: "On a Theory of a Spherical Milne Problem." In the Coll., Some Mathematical Problems of Neutron Physics. MGU Pub., 1960, p. 56.

193. Maslennikov, M. V.: "On a General Problem of the Theory of Slowing Down of Neutrons." Rep. Acad. Sc. USSR, 118, #2, 259 (1958).

194. Maslennikov, M. V.: "On the Vick Problem." Rep. Acad. Sc. USSR, 120, #1, 59 (1958).

195. "Materials of the U.S. Atomic Energy Commission." Nuclear Reactors. Moscow, For. Li. Pub., 1956.

196. Mayer, W.: "Method of Approximate Solution of Eigen-Value Problems as Applied to Oscillation Problems." Annals of Phys., 5, 297 (1931).

197. Mayman, N. N.: "Some Applications of a Method of Finite Differences to Differential Equations." Trans. 3rd All-Union Math. Cong., Acad. Sc. USSR Pub., vol. 1, (1956), p. 60.

198. Marrey, R.: "Physics of Nuclear Reactors." Moscow., Atm. Pub., 1959.

199. Mertens, R.: "On Milne's Problem for a Rayleigh Single Scattering Law $1 \neq \cos^2 \theta$." Compt. Rend. Acad. Sci. Colon., 238, 53 (1954).

200. Mertens, R.: "On the Multiple Diffusion of Charged Particles." Compt. Rend. Acad. Sci. Colon., 236, 18, 1753 (1953).

201. Mertens, R.: "On the Solution to the nth Approximation of Multiple Diffusion Problems." Compt. Rend. Acad. Sci. Colon., 237, 23, 1644 (1953).

202. Miln, V. E.: "Numerical Solution of Differential Equations." Moscow, For. Lit. Pub., 1955.

203. Miln, V. E.: "Numerical Analysis." Moscow, For. Lit. Pub., 1951.

204. Mikhaylus, F. F.: "Application of a Variational Method for the Calculation of the Critical Mode of a Cylindrical Reactor." In the Coll., Some Math. Prob. of Neutron Phys. MGU Pub., 1960, p. 165.

205. Mikhlin, S. G.: "Direct Methods in Mathematical Physics." Moscow--Leningrad, State Tech. Theor. Pub., 1951.

206. Morozov, V. N.: "On a Problem Concerning the Solution to Kinetic Equations by means of the Sn-Method." Coll., Theory and methods of calculating reactors. State Atm. Pub., 1962 (on the presses).

207. Morton, K.: "Calculation of the Probability of Resonance Escape." In the Coll., Neutron Phys. Moscow, Atm. Pub., 1959, p. 594.

208. Mostovoy, V. I., Dikarev, V. S., Yegiazarov, M. B. and Saltykov, Yu. S.: "Measuring the Spectrum of Neutrons in Uranium-water Lattices." In the Coll., Nuclear reactors and nuclear power engineering. Moscow, Atm. Pub., 1959.

209. Mukhin, K. N., Makarvin, V. K., Venediktov, A. P.:an:Diffusion of Heat Neutrons in Anisotropic Media." In the Coll., Neutron Phys. Moscow, State Atm. Pub., 1961.

210. Nelkin, M. and Parks, D.: "Physics Review", 119, 1060 (1960).

211. Nelkin, M.: "Slow Neutrons Inelastic Scattering and Neutron Thermalization." Report at a symposium on inelastic scattering. Vienna, 1960.

212. Nelkin, M.: "Neutron Thermalization." II -- Heavy Crystaline Moderator. Journal of Nuclear Science and Engineering, 2, 199 (1957).

213. Nikolayev, M. N.: "On Souswell's Relaxation Method." Trans. of the V. A. Steklov Math. Inst. Acad. Sc. USSR Pub., #28, 1949.

214. Nikolayshvili, Sh. S.: "Passage of gamma-radiation through a plane layer." In the collec., Some Math. Prob. of Neutron Phys. MGU Pub., 1960, p. 183.

215. Nikolayshvili, Sh. S.: "Approximate Solution to a Transfer Equation by the Method of Moments." Atm. Ener., 9, #2 (1961).

216. Novozhilov, A. I. and Shikhov, S. B.: "Method of Averaging Nuclear Constants for Calculating a Fast Reactor with the Allowance for the Importance of Neutrons." Atm. Ener., 8, #3, 209 (1960).

217. Okrent, D. et al.: "Survey of Theoretical and Experimental Fundamentals of Physics of a Fast Neutron Reactor." In the collec., Exper. Reac. and Phys. Reac. Moscow, State Tech. Pub., 1956.

218. Orlov, V. V., Golashvili, T. V. and Vaskin, A. I.: "Resonance Absorbtion of Neutrons in Heterogeneous Reactors." In the collec., Neutron Phys. Moscow, State Atm. Pub., 1961.

219. Orlov, V. V.: "Albedo Equations in the Theory of Diffusion and Slowing Down of Neutrons." In the collec., Neutron Phys. Moscow, State Atm. Pub., 1961.

220. Orlov, V. V. and Luk'yanov, A. A.: "Influence of Interferrence of Potential and Resonance Scattering on Resonance Absorbtion of Neutrons in a Substance." Collec., Theory and methods of calculating reactors. State Atm. Pub., 1962. (in the presses).

221. Orlov, V. V.: "Mutual Shielding of Blocks of a Resonance Absorber of Neutrons in a "Close" Lattice." _____ Atm. Ener., 4, #6, 531 (1958).

222. Orlov, V. V. and Tsypin, S. G.: "Protection of Transport Installations with a Nuclear Engine." Collec. of Articles. Moscow, For. Lit. Pub., 1961.

223. Payerls, R.: "Quantum Theory of Solids." Moscow, For. Lit. Pub., 1956.

224. Peierls, R.: "Critical Conditions in Neutron Multiplication." Proc. Cambr. Phil., 35, 610 (1939).

225. Petrov, Yu. V.: "Resonance Absorbtion in Closely-located Small Blocks." Atm. Ener., #4 (1957).

226. Petrovskiy, I. G.: "Lectures on Equations with Partial Derivatives." Moscow, State Tech. Theoret. Pub., 1953.

227. Placzek, G.: "On the Theory of the Slowing Down of Neutrons in Heavy Substances." Phys. Rev., 69, 9--10, 423 (1946).

228. Placzek, G. and Seidel, W.: "Milne's Problem in Transport Theory." Phys. Rev., 72, 7, 550 (1947).

229. Placzek, G. and Van Hove, L.: "Interference Effects in the Total Neutron Scattering Cross-Section of Crystals." Nuovo cimento, 1, 233 (1955).

230. Placzek, G.: "Incoherent Neutron Scattering by Polycrystals." Phys. Rev., 93, 895 (1954).

231. Placzek, G.: "The Scattering of Neutrons by Systems of Heavy Nuclei." Phys. Rev., 86, 377 (1952).

232. Polozhiy, G. N.: "Numerical Solution of Dimensional and 3-dimensional Boundary Problems of Mathematical Physics and Functions of Discrete Argument." Pub. House of T. G. Shevchenko Kiev State University, 1961.

233. Ptytsyn, A. R.: "On a Problem concerning the Finding of Space-energy Distribution of Neutrons from a Plane Source in an Infinite Medium." Atm. Ener., 9, #3, 216 (1960).

234. Ptitsyns, N. V.: "Application of Variational Method to Certain Generali-
zations of Milne's Problem." In the collection, Some Math. Prob. of Neut. Phys.
MGU Pub., 1960, p. 28.

235. Pupko, V. Ya.: "Analysis of the Dependence Between a Critical Load and Cri-
tical Exchange for Reactors of Various Types." Supplement #1 to Atm. Ener. (1958).

236. Pupko, V. Ya. and Yermakova, L. I.: "On Parameters of a Reactor with a
Minimum $ Critical Load." Atm Ener., 7, #6, 560 (1959).

237. Reynolds, A., Nelkin, M., Rosenblum, M. and Whitmore, U.: "Thermalization
of Neutrons on Chemically Combined Hydrogen and Carbon." In the collection, Neut.
Phys. Moscow, Atm. Pub., 1959, p. 648.

238. Richtmayer, R. D.: "Difference Methods of Solving Boundary Problems."
Moscow, For. Lit. Pub., 1960.

239. Romanov, Yu. A.: "Accurate Solutions to a Single-speed Kinetic Equation
and their Utilization for Calculating Diffusion Problems (improved diffusion me-
thod)." In the collection, Invest. Crit. Param. Reac. Sys. Moscow, Atm. Pub.,
1960.

240. Romanova, L. M.: "Milne's Problem for a Half-space with an Anisotropic
Scattering and Capture of Neutrons." In the collection, Some Math. Prob. Neut.
Phys. MGU Pub., 1960, p. 8.

241. Rumyantsev, G. Ya.: "Boundary Conditions in the Method of Spherical Har-
monics." Atm. Ener., #1 (1961).

242. Rumyantsev, G. Ya.: "On the Utilization of Even Approximations in the Me-
thod of Spherical Harmonics." In the collection, Invest. crit. param. reac. sys.
Moscow, Atm. Pub., 1961.

243. Ryzhik, I. M. and Gradshtein, I. S.: "Tables of Integrals, Sums of Series
and Derivatives." Moscow, State Tech. Theoret. Pub., 1956.

244. Ryaben'kiy, V. S. and Fillippov, A. F.: "On the Stability of Difference
Equations." Moscow, State Tech. Theoret. Pub., 1956.

245. Saul'yev, V. K.: "On a Problem of Solving a Problem concerning eigen-values
by a Method of Finite Differences." Moscow, In the collection, Computer Math.
and Computer Technique. Acad. Sci. USSR Pub., vol. 2, 1955.

246. Saul'yev, V. K.: "Integrating of Parabolic Equations by the Grid Method."
Phys. Math. Pub., 1960.

247. Saul'yev, V. K.: "Note on the Question concerning the Calculation of Cy-
lindrical Reactors." Atm. Ener., #7, 53 (1957).

248. Saul'yev, V. K.: "On One Method of Numerical Integration of Diffusion Equa-
tions." Rep. Acad. Sci. USSR, 115, #6, 1077 (1957).

249. Southwell, R.: "Relations Methods in Engineering Science." Oxford Univ.
Press, 1943.

250. Skvortsov, S. A.: "Water-aqueous Reactors (VVER) in the USSR." In the collection, Nuclear reactors and nuclear power engineering. Moscow, Atm. Pub., 1959, p. 105.

251. Smelov, V. V.: "On an Approximate Method of Homogenization of a Heterogeneous Reactor." In the collection, Physics of nuclear reactors. Moscow, Atm. Pub., 1959, p. 496.

252. Smelov, V. V.: "Calculation of Spectrum of Heat Neutrons." Atm. Ener., 6, #5, 546 (1959).

253. Smelov, V. V.: "On a Question concerning Thermalization of Neutrons." Atm. Ener., 3, #10, 317 (1957).

254. Smelov, V. V.: "Numerical Method of Calculating Space-energy Spectrum of Heat Neutrons and an Approximate Method of Homogenization of a Heterogeneous Reactor." Dissertation, 1959.

255. Smirnov, V. I.: "Course in Higher Mathematics." Vol. 3--4. Moscow, State Tech. Theoret. Pub., 1951.

256. Sobolev, V. V.: "Transfer of Radiant Energy in the Atmospheres of the Stars and Planets." Moscow, State Tech. Theoret. Pub., 1956.

257. Sobolev, V. V.: "New Method in the Theory of Light Scattering." Astron. Journ., 28, #5 (1951).

258. Sobolev, S. L.: "Equations of Mathematical Physics." Moscow, State Tech. Theoret. Pub., 1954.

259. Sobolev, S. L.: "Some Contemporary Questions of Computer Mathematics." Trans. 3rd All-Union Math. Cong. Moscow, Acad. Sci. USSR Publ., vol. 2, 1956.

260. Sobolev, S. L., Lyusternik, L. A. and Kantorovich, L. V.: "Functional Analysis and Computer Mathematics." Trans. 3rd All-Union Math. Cong. Moscow, Acad. Sci. USSR Publ., vol. 2, 1956.

261. Sobolev, S. L. and Mukhina, G. V.: "Determination of Thermal Stresses in a Medium with Bubbles." Atm. Ener., 5, #2, 178 (1958).

262. Spenser, L. and Fano, U.: "Penetration and Diffusion of X-Rays: Calculation of Spatial Distribution by Polynomial Expansion." Journ. Res. Nat. Bur. Standards, 46, 446 (1951).

263. Spinrad, B.: "Anisotropic Diffusion Lengths in Diffusion Theory." Journ. Appl. Phys., 26, 548 (1955).

264. Spinrad, B., Chernik, Zh. and Korngold, N.: "Resonance Capture in Uranium and Thorium Blocks." In the collection, Neutron Phys., Moscow, Atm. Publ., 1959, p. 539.

265. Stuart, G.: "Multiple Scattering of Neutrons." Journ. Nucl. Sci. and Eng. 2, 617 (1957).

266. Stuart, G., Hofman, P. and Storm, M.: "Physical Basis of Calculation of

Intermediate Neutron Reactors." Rep. #2381. Trans. Int'l Conf. on Peaceful Use of Atm. Ener. Rep. For. Scientists, vol. 3, Moscow, Atm. Publ., 1959.

267. Stuart, G. and Zweifel, P.: "Self-shielding and Doppler Effect at Absorbtion of Neutrons." In the collection, Neutron Phys. Moscow, Atm. Publ., 1959, p. 600.

268. Soodak, G. and Campbell, K.: "Elementary Pile Theory." N.Y., 1950.

269. Tikhonov, A. N. and Samarskiy, A. A.: "Equations of Mathematical Physics." Moscow, State Tech. Theoret. Publ., 1953.

270. Tikhonov, A. N. and Samarskiy, A. A.: "On the Convergence of Difference Diagrams in the Class of Disruptive Coefficients." Rep. Acad. Sci. USSR, 124, #3, 529 (1959).

271. Tikhonov, A. N. and Samarskiy, A. A.: "On Uniform Difference Diagrams." Rep. Acad. Sci. USSR, 122, #4, 562 (1958).

272. Tikhonov, A. N. and Samarskiy, A. A.: "On One of the Best Uniform Difference Diagrams." Rep. Acad. Sci. USSR, 124, #4, 779 (1959).

273. Tikhonov, A. N. and Samarskiy, A. A.: "On Difference Diagrams for Equations with Disruptive Coefficients." Rep. Acad. Sci. USSR, 108, #3 (1956).

274. Thompson, A.: "Numerical Computation of Neutron Distribution and Critical Size." Journ. Appl. Phys., 22, 1223 (1951).

275. Turchin, V. F.: "Scattering of Neutrons on Crystals in an Incoherent Approximation." In the collection, Neutron Phys., Moscow, Atm. Publ., 1961.

276. Turchin, V. F.: "Solution of an Equation of Slowing Down of Neutrons by means of 'conjugate moments'." In the collection, Neutron Phys., Moscow, Atm. Publ., 1961.

277. Turchin, V. F.: "Scattering of Neutrons in Liquids." Report presented at a Symposium on Scattering of Neutrons in Solids and Liquids. Vienna, 1960.

278. Usachev, L. N.: "Equation for Importance of Neutrons of Kinetic Reactor and Theory of Distubbances." In the collection, Reactor construction and theory of reactors. Moscow, Acad, Sci. USSR Publ., 1955.

279. Usachev, L. N.: "Methods of Calculating Reactors Operating on Fast Neutrons." Dissertation, 1954.

280. Usachev, L. N. and Stavinskiy, V. S.: "Some Questions of the Theory of Intermediate Reactors " (memorandom of A. S. Romanovich). Account of the Acad. Sci. USSR, 1956.

281. Faddayev, D. K. and Faddeyeva, V. N.: "Computer Methods of Linear Algebra." Phys. Math. Publ., 1960.

282. Feinberg, S. M.: "Some Questions on the Theory of a Uranian-Water Lattice." Report at session of Acad. Sci. USSR, 1956.

283. Feinberg, S. M.: "Heterogeneous Methods of Calculating Reactors." Survey of results and comparison with experiments. In collection, Reactor construction and theory of reactors. Moscow, Acad. Sci. USSR Publ., 1955.

284. Feinberg, S. M., Konobeyevskiy, S. T., Dollezhal', N. A. et al.: "Research Reactor S. M. with a Power of 50 Mw." Atm. Ener., 8, #6, 493 (1960).

285. Feinberg, S. I., Antsferov, Ye. S., Katkov, V. P. et al.: "Burnup in a Water-moderated Power Reactor and Experiments with a Uranium-Water Lattice." Rep. #2145. Trans. 2nd Intern'l. Conf. on Peaceful Use of Atm. Ener. (Geneva, 1958). Rep. Sov. Scientists, vol. 2, Moscow, Atm. Publ., 1959.

286. Feinberg, S. M., Vorob'yev, Ye. D., Gryazev, V. I. et al.: "Intermediate Reactor for Obtaining Currents of Neutrons of High Intensity." Rep. #2142. Trans. 2nd Intern'l. Conf. on Peaceful Use of Atm. Ener. (Geneva, 1958). Rep. Sov. Scientists, vol. 2, Moscow, Atm. Publ., 1959.

287. Fermi, E.: "On the Motion of Neutrons in Hydrogenated Substances." Scien. Research, 2, 1--2, 13 (1936).

288. Finkelstein: Physics Review, 72, 907 (1947).

289. Foderado, A. and Garabedian, H.: "A New Method for the Solution of Group Diffusion Equations." Journ. Nucl. Sci. and Engr., 8, 44 (1960).

290. Fort, E. and Frankel, S.: "Stability Conditions in the Numerical Treatment of Parabolic Differential Equations." Math. Tables and Other Aids Comput., 7, 135, 43 (1953).

291 Franel, S.: "Convergence Rates of Iterative Treatments of Partial Differential Equations." Math. Tables and Other Aids Comput., 4 (1950).

292. Frish: Progress of Nuclear Physics, 1, 175 (1950).

293. Froman, P. O.: "On Neutron Diffraction Phenomena According to the Kinematic Theory." 2. Arkiv fys., 4, 191 (1952).

294. Franicis, N., Hurwitz, H. and Zweifel, P.: "Critically and Flux Calculations for Hydrogeneous Assemblies." Journ. Nucl. Sci. and Engr., 2, 3 (1957).

295. Fucks, K.: "Perturbation Theory in Neutron Multiplication Problems." Proc. Phys. Soc., 62, 791 (1949).

296. Fursov, V. S.: "Works of the Academy of Sciences of the USSR on Uranium-Graphite Reactors." Session of the Acad. Sci. USSR on peaceful use of atm. ener., 1--5 July 1955. Plenum meeting. Moscow, Acad. Sci. USSR Publ.

297. Harvey, G. and Sanders, J.: "Review of Data on Effective Cross-Sections and Yields of Neutrons for U^{233}, U^{235}, Pu^{239}." In collection, Progress in the Field of Nuclear Power Engineering. Moscow, For. Lit. Publ., 1958, p. 9.

298. Hartree, D.: "A Method for the Numerical Integration of the Linear Diffusion Equation." Proc. Cambr. Phyl. Soc., 54, 2 (1958).

299. Hyman, M.: "On the Non-Iterative Numerical Solution of Boundary Value Problems." Appb. Scient. Res., 2 (1952).

300. Zemach, A. and Glauber, R.: "Dynamics of Neutron Scattering by Molecules." Phys. Rev., 101, 1 (1952).

301. Zweifel, P. and Hurwitz, H.: "Transformation of Scattering Cross-Sections." Journ. Appl. Phys., 25, 10, 1241 (1954).

302. Chandrasekar, S.: "Transfer of Radiant Energy." Moscoe, For. Lit. Publ., 1953.

303. Chernik, D.: "Theory of Uranium-Water Lattices." In collection, Experimental Reactors and Physics of Reactors. Moscow, State Tech. Theoret. Publ., 1956.

304. Chuyanov, V. A.: "On the Convergence of an Approximate Solution to a Kinetic Equation (Gauss-type quadrature method)." In collection, Some math. prob. neut. phys. Moscow, MGU Publ., 1960, p. 199.

305. Chuyakov, V. A.: "Multigroup calculation of the reactor of an atomic electrical power plant operating on a rapid electronic calculating machine 'Strela'." Atm. Ener., 7, #1, 64 (1959).

306. Shevelev, Ya. V.: "Diffusion of Neutrons in a Flat Uranium-Water Lattice." Atm. Ener., 2, #3, 224 (1957).

307. Sheldon, J.: "On the Numerical Solution of Elliptic Difference Equations." Math. Tables and other Aids Comput., 9, 101, #51, 1955.

308. Shirkov, D. V.: "Method of Synthetic Nucleus for Problems of Diffusion of Neutrons in a Hydrogen-containing Medium." Supplement #1 to Atm. Ener., 1958.

309. Shirkov, D. V.: "Method of Synthetic Nucleus for Problems of Diffusion of Neutrons in Moderators without Hydrogen." Supplement #1 to Atm. Ener., 1958.

310. Shikhov, S. B.: "Calculation of the Influence of the Change in Dimensions on a Critical Mass of a Fast Reactor by means of the Theory of Perturbances." Atm. Ener., 6, #2, 162 (1959).

311. Schofield, P.: "Space-time Correlation Function Formalism for Slow Neutron Scattering." Phys. Rev., 4, 239, (1960).

312. Egelstraf, P.: "Resonance Structure of U233, U235 and Pu239." Prog. in Field of Nucl. Pow. Engr. Moscow, For. Lit. Publ., 1958, p. 76.

313. Engel, H.: P3-Approximation for Determining the Thermal Utilization." Journ. Atm. Ener., 4, 4 (1958).

314. Ehrlich, R. and Hurwitz, H.: "Multigroup Methods for Neutron Diffusion Problems." Nucleonics, 12, 2, 23 (1954).

315. Yu z D: "Neutron Investigations on Nuclear Boilers." Moscow, For. Lit. Publ., 1954.

316. Yanenko, N. N.: "On One Difference Method of Calculating a Multidimensional Equation of Heat Conductance." Rep. Acad. Sci. USSR, 125, #6, 1207 (1959).

317. Yanenko, N. N.: "On Economic Unequal Functions." (Method of fractional steps). Rep. Acad. Sci. USSR, 134, #5, 1034 (1961).

318. Yanke, Ye. and Emde, F.: "Tables of Functions." Moscow, State Tech. Theo. Publ., 1951.

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE	Nr. Copies	MAJOR AIR COMMANDS	Nr. Copies
		AFSC	
		SCFTR	1
		ASTIA	25
HEADQUARTERS USAF		TD-Bla	5
		TD-Blb	3
AFCIN-3D2	1	SSD (SSF)	2
ARL (ARB)	1		

OTHER AGENCIES

CIA	1
NSA	6
AID	2
OTS	2
AEC	2
PWS	1
NASA	1
RAND	1